Relationship between Central Corneal Thickness, Vitreous Chamber Depth and Axial Length of Adults in a Nigerian Population.

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Abstract

The central corneal thickness (CCT), Vitreous chamber depth (VCD) and axial length (AL) are important ocular parameters used in the assessment of ocular health in relation to some ocular morbidities. Determining the differences in these parameters in relation to each other is fundamental to understanding the general eye health and also aid in developing strategies to help early diagnoses and management of some ocular conditions. Sixty-six (66) participants consisting of thirty-one (31) males and thirty-five (35) females between 18 to 68 years participated in this study. CCT and other ocular biometry was measured with Ultrasound pachymetry and ultrasonography. VCD was obtained by subtracting the sum of anterior chamber depth and lens thickness, from AL. All data were analyzed with Statgraphics plus version 5.1 and SPSS version 22.0. The mean age, CCT, VCD and AL were 37.2 ± 11.6 years, 536.71±23.89 µm, 16.30±0.80mm and 23.60±0.80mm respectively. Statistically significant positive correlation was found between VCD and AL ($r= 0.83$, $r2= 69.3\%$, $p<0.0001$). The difference in mean VCD (0.49mm) between males (16.63±0.89mm) and females (16.14±0.66mm) was statistically significant ($p= 0.015$). Similarly, the difference in mean AL (0.54mm) between males (23.89±0.78mm) and females (23.35 ± 0.74mm) was statistically significant ($p= 0.005$). The linear association between CCT, VCD and AL was not significant. AL and VCD were not significantly affected by age but a significant negative linear relationship was found between CCT and age. The result of this study will aid in early diagnoses of some ocular morbidity by identifying risk factors associated with these parameters.

Keywords: Central corneal thickness, Vitreous chamber depth, Axial length

Introduction

The cornea is the most powerful refracting surface of the optical system of the eye[1]. It accounts for two-thirds of the eye's focusing power. The transparency of the cornea with its appropriate refractive power determines the production of a sharp image at the retinal receptors. The refractive power of the cornea is in turn determined by its curvature and the difference in refractive indices[2] between it and air on one hand and aqueous on the other. Corneal thickness as measured by pachymetry is a sensitive indication of the cornea health status. Its measurement is useful for the diagnosis of disease, determining the effectiveness of medical and surgical treatment and the evaluation of contact lens wear[3].

Central Corneal thickness (CCT) is an important indicator

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of cornea status and affects intraocular pressure (IOP) measurements.[4] However, there is no general consensus with respect to how CCT varies with refractive error, corneal curvature, vitreous chamber depth (VCD), anterior chamber depth (ACD) and axial length (AL). The axial length is the distance between the anterior and posterior poles of the eye.[5] In vivo, it is measured either by ultrasonography or by partial coherence interferometry (PCI). These measurements represent the distance between the anterior pole and Bruch's membrane. The axial length of the eye at birth is approximately 17 mm and reaches approximately 24 mm in adulthood. It is typically longer than 24 mm in myopes and shorter than 24 mm in hyperopes. Each millimetre of change in axial length of the eye corresponds to approximately 2.5 D.[6] It has been found that myopes have longer axial length than hyperopes[3] and also they are known to have the thinnest corneas (449.65µm±39.36µm) followed by emmetropes (542.66µm±46.35µm) and hyperopes (557.67µm± 41.83µm)[7].

There are four ocular structures contributing to the refractive status of a given human eye, including the cornea, aqueous humour, lens and the vitreous humour. Myopia and other refractive-error disorders are consequences of uncoordinated contributions of ocular components to overall eye structures. In other words, the cornea and lens fail to compensate for axial length (AL) elongation (myopia) or shortening (hyperopia). Thus, parameters closely linked to measurements of these parts such as corneal curvature, anterior chamber depth (ACD), lens thickness (LT), vitreous chamber depth (VCD) and AL are widely evaluated in the study of eye diseases. In general, AL increases rapidly in the early stages of life then slowly increases until adulthood,[8] then decreases in old age and AL also reflects the sum of the thickness of the lens, ACD and the length of the vitreous chamber.

The VCD and the AL are considered to be the most representative indicators for the growth of the posterior segment, as well as the main factors in the progression of myopia[9]. The VCD occupies posterior 4/5ths of the eyeball. This chamber consists of the space between the lens and the retina, and is filled with a transparent gel called the vitreous humour. However, the vitreous has a viscosity two to four times that of pure water giving it a gelatinous consistency[10]. It also has a refractive index of 1.336. Recent research has highlighted the importance of central corneal thickness (CCT) in relation to several ocular conditions. Despite having an extensive knowledge of the structure and function of the cornea, little is known about the pathways that determine CCT. There are data to suggest however that CCT has a strong genetic component. There is no general consensus with respect to how CCT relates with axial length of the eyes and or anthropometric parameters[11-13].

A fundamental understanding of central corneal thickness (CCT), Vitreous chamber depth (VCD) and Axial Length (AL) is required due to the fact that these parameters play an important role in early diagnosis of some ocular conditions such as glaucoma and helps to understand the refractive status of a patient. This study therefore aims to determine the relationship between central corneal thickness (CCT), vitreous chamber depth (VCD) and Axial Length (AL) of adults in a Nigerian population.

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MATERIALS AND METHODS

This was an observational, prospective, cross sectional study to determine the relationship between central corneal thickness, axial length and vitreous chamber depth carried out at Rachel eye centre, Area 11, Garki, Abuja. The participants were recruited after detailed optometric examination that included best corrected visual acuity, refraction, slit-lamp examination, applanation tonometry and fundus examination. Only participants who had no ocular disease, no previous ocular surgery, normal IOP, normal blood pressure, refractive error less than or equal to ±0.50D and participants without comorbidities affecting CCT such as diabetes mellitus were recruited. Exclusion criteria were previous ocular surgery (any type of eye surgery), glaucoma, trauma history, external eye disease, extensive pterygium, corneal edema or dystrophy, aphakia, amblyopia and lack of cooperation.

The study was approved by the Ethics and Research Committee of the Department of Optometry, Faculty of Life Sciences, University of Benin, Benin City, Edo State, Nigeria, in accordance with the tenets of Helsinki declaration for human participants.

Procedure

Measurements were taken on the right and left eye of each subject throughout this research after sterilization of the probe. The subject was comfortably seated with the head upright and ayes in the primary position of gaze. The probe was sterilized with 70% alcohol and allowed to air-dry. A drop of topical anaesthetic (Tetracaine HCl 0.1%) was instilled in subject's eye. The probe was carefully aligned perpendicularly to and lightly applanating the cornea.

CCT

The central corneal thickness was measured by ultrasound pachymetry using SW-1000P ultrasound Pachymeter (Tianjian Suowei Electronics Technology Co., LTD, China). Sterilized Ultrasound pachymeter probe (Speed: 1640ms^{-1}, Frequency: 20 MHz). The probe will be carefully aligned perpendicularly to and lightly applanating the anaesthetized cornea. Five readings were continually taken and the average calculated by the instrument as measured CCT.

AL, VCD, LT and ACD

A-Scan ultrasonography using I-2100 A Scan Biometer (Cima Technology Inc., USA). Sterilized A-Scan Ultrasound biometer probe (Speed: 1548ms^{-1}, Frequency: 10 MHz). The probe will be carefully aligned perpendicularly to and lightly applanating the anaesthetized cornea. Five readings were continually taken and the average calculated by the instrument as measured AL, VCD, LT and ACD.

The subject was comfortably seated with the head upright and ayes in the primary position of gaze. The probe was sterilized with 70% alcohol and allowed to air-dry. A drop of topical anaesthetic (Tetracaine HCl 0.1%) was instilled in subject's eye. The probe was carefully aligned perpendicularly to and lightly applanating the cornea. At least ten readings are continually taken and the average calculated as the measured central corneal thickness (expressed in microns).

For the axial length measurement, subject's and instrument preparations are same as in pachymetry. The axial length was displayed on liquid crystal display (LCD) screen through output interface. Three measurements were taken for each subject and the average calculated as the measured variable. All measurements were taken between 10.00 am and 12.00 noon. All measurements were taken by the same observer to avoid inter-observer bias.

Statistical Package

All data obtained were analyzed with Statgraphics plus ver. 5.1 (Statistical graphics corp., USA) and SPSS ver. 22.0 (SPSS Inc, Chicago IL, USA). Measures of spread including standardized kurtosis and standardized skewness were derived. The measured variables (CCT, spherical equivalent refractive error, axial length, vitreous chamber depth) was tested for normality with the Kolmogorov Smirnov Z - test (normal distribution when the lower p-value is greater than 0.05). Analysis of variance (ANOVA) was used to compare variables across age groups and post hoc test for pair wise comparison within the groups. Gender-related differences in measured variables were tested with student's t-test (unpaired). The correlation or association between variables was tested using regression analysis. Statistically significant will be declared when p-value is < 0.05.

Results

A total of 66 (n=66) participants (132 eyes) aged between 18 to 68 years with mean age of 37.2 ± 11.6 years, consisting of 31 males and 35 females participated in this study (Table 2). The difference in mean age between males (38.8±12.0years) and females (35.7±11.1years) was not statistically significant (unpaired t-test: t= 1.09, df= 64, p= 0.28). The difference in mean CCT between males (536.7±38.38µm) and females (536.7±19.50µm) was not statistically significant (p>0.05) (Table 4). However, the difference in mean VCD (0.49mm) between males (16.63±0.89mm) and females (16.14±0.66mm) was statistically significant (unpaired t-test: t= 2.571, df= 64, p= 0.015). Men had deeper VCD than their female counterparts (Table 4). Similarly, the difference in mean AL (0.54mm) between males (23.89±0.78mm) and females (23.35 ± 0.74mm) was statistically significant (t= 2.90, df=64, p= 0.005). By this men have longer axial length than women.

The mean CCT was 536.7 ± 23.89µm (Table 4). The correlation between CCT and age showed a negative trend, though not statistically significant (r = - 0.20, r^2 = 3.8%, p = 0.12). The liner regression model is represented by: CCT= 551.7- 0.404 AGE (Figure 1). The model as fitted explains 3.8% of the variability in CCT. From the regression model, a prediction of approximately 4.0µm decreases in CCT per decade can be made. The mean VCD was 16.37 ± 0.81mm (Table 4). Regression analysis performed on VCD and age showed no statistically significant correlation (r^2= - 0.07, p = 0.58). The linear regression model is represented by: VCD = 16.55 – 0.05 AGE. The mean AL was 23.60 ± 0.80mm (Table 4). There was no statistically significant correlation between AL and age (r= 0.078, p= 0.53). The linear regression model is represented by: AL = 23.40 + 0.05 AGE.

There was no statistically significant linear relation between CCT and VCD (r= 0.014, p= 0.91). The linear regression model is represented by: CCT = 543.57 - 0.419 VCD. In the same vein, the correlation between CCT and AL (Table 4) was not statistically significant (r=0.032, P= 0.80). The linear regression model is represented by: CCT= 559.45-0.963AL. Statistically significant positive correlation was found between VCD and AL (r= 0.83, r^2= 69.3%, p<0.0001). The model as fitted explains 69.3% of the variability in VCD (Figure 2).

Discussion

When making decisions in clinical practice, parameters that are quantifiable are very important to aid accurate diagnosis of a clinical condition and cannot be over emphasized. Quantifiable parameter such as CCT has proven to be of great usefulness in the diagnosis of ocular conditions such as Glaucoma and also an indicator of corneal health status. In this study, the mean CCT was higher than the mean CCT reported by some other researchers[14-18] but was closely in line with Doughty and Zaman[19] and Atchison et al.,[20] they reported a mean CCT of 536 ± 31 µm and of 534 ± 0.047 µm respectively. A non-statistically significant negative correlation between CCT and age was found in this study, some studies showed a similar finding although statistically significant[21-23].

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Iyamu and Ituah[16] and Mohamed *et al*[24] reported that there was no significant association between CCT and age. Doughty and Zaman[19], found that age did not appear to influence CCT across the studies of Caucasian groups, but age-related decrease were reported in non-Caucasian groups although some recent studies have reported age effects on CCT[17, 25-30], while other studies have not found any age effect on CCT.[31-34] From the regression equation CCT= 551.7-0.404 AGE, a decrease of approximately 4.0 µm in CCT for every decade was predicted in this study. Eballe et al.[14] also reported a similar finding that CCT decreases by 4.2 µm for each 10 years of life. Iyamu *et al*.[21] also reported a statistically significant negative correlation between CCT and age (r = −0.25, p = 0.021) that was represented by CCT = 571.93–0.513AGE. From the equation given in their study, a decrease of approximately 5.0 µm in CCT for every 10-year increase in age was predicted, and this was similar to that obtained in this study. This relationship between CCT and age that is the change in CCT with age can be attributable to changes in the structural biomechanical properties of the cornea that occur as a person ages[35]. Kamiya *et al*[36], also reported that biomechanical data for the cornea change during the course a lifetime, but could not identify significant changes in age-related CCT. Thinning of the cornea at a rate of 3–7 µm per decade has been observed in older age in some ethnic groups[23]. Referring to theory based on histologic studies, the corneas of older people are thinner because of a reduction in keratocyte density and possible destruction of collagen fibers, and senior individuals are exposed to environmental factors for a longer period of time, which might influence corneal structure[37].

The difference in mean CCT between males (536.7±38.38µm) and females (536.7±19.50µm) was not statistically significant (p>0.05). This was similar to the report of Hawker et al., 38 they found out that there was no significant difference in CCT between men and women (mean CCT 546.1µm and 542.7µm respectively, p=0.15). Other studies[11,29,30,39] also suggest a gender difference in ocular biometrics with women having a significantly thinner cornea. Also it was observed in Iyamu et al.[21] that the mean CCT of males was higher (552.8µm) than females (543.8µm) however the difference in mean CCT between males and females was not statistically significant (P=0.41) in line with this study and also favours some studies[16,18,&40], they reported that gender-related differences in CCT was not significant (p>0.05). Doughty and Zaman,[19] found no apparent gender influence across Caucasian group studies. Some studies,[20,27] have reported males having slightly thicker corneas than females, but others have not found gender-related differences.[17, 25, 28, 31 & 32]

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The failure in this study to detect a relationship between CCT and AL was in line with some studies [29,41 & 42]. Chang *et al*.[43] demonstrated significantly thinner CCTs in eye balls with greater axial length (r= -0.502, p<0.001). They proposed that as the surface area of the cornea is increased, the stromal became thinner and reduced CCT could be expected as the eyeball elongated axially. Although their sub-population may be too small to give a true relationship between AL and CCT in the general population.

The mean VCD gotten from this study is in keeping with the VCD reported in adult population in some studies which ranged between 14.42 to 16.60mm [44-47]. In this study no statistically significant correlation was found between VCD and Age (r= - 0.07, p = 0.58), although there was a negative trend which might suggest a decrease in VCD with age but not statistically significant. This was in line with Atchison et al.[20] and Norton *et al*.,[48] although they reported that VCD increased rapidly until 15 days of visual exposure, and then decreased because the lens thickness increased more rapidly than axial length. The Linear regression model in this study might have also suggested a decrease of 0.5mm. It must also be noted that our data come from a cross-sectional study, therefore no judgment can be made about the trend of VCD changes with age and longitudinal studies are needed for a definite answer.

The difference in mean VCD (0.49mm) between males (16.63 ± 0.89mm) and females (16.14 ± 0.66mm) was statistically significant (unpaired t-test: t= 2.51, df= 64, p= 0.015). Men had deeper VCD than their female counterparts. This result agrees with the finding of Shufelt *et al*.[13] and Atchison *et al*.[20] which showed that males had longer VCD than females. The older women had significantly shallower VCD when compared with the younger women (P = 0.005). These gender-related differences in VCD were statistically significant after adjusting for height (P =0.03). Wong *et al*.[49] also reported shorter and shallower VCDs for women. Based on these findings, inter-gender differences in refractive errors are expected[45].

A statistically significant positive correlation was found between VCD and AL (r= 0.83, r^2= 69.3%, p<0.0001). This was in line with the finding of Weihua et al50, who reported that AL increase was due to lengthening of the vitreous chamber. However, Osuobeni *et al*[51], reported that there was no relationship between VCD and AL. The mean AL in this study was very similar to previous studies[44 & 45, 52 &53]. AL varies between 22.6 mm to 24.09 mm in majority of studies, and the mean AL in our study falls in the midrange. Regression analysis performed on AL and the effect of age did not agree with Atchison *et al*[20], who reported significant age changes between AL and age, and that axial length increased 0.011 mm/year and it most likely reflects the refractive correction pattern with change in age rather than ongoing growth of the eye itself. Also Biino *et al*[54], found that AL increases rapidly in the early stage of life, then slowly increases

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until adulthood, then decreases in old age, showing a quadratic relationship between AL and age. However, this study was in line with some studies [13,39] which observed no age-related differences in axial length (p>0.05). An explanation for this is that once the eye has attained its adult size, little change occurs in the axial length during adulthood and with aging.

In this study the difference in mean AL between males (23.89±0.78mm) and females (23.35 ± 0.74mm) was statistically significant (t= 2.90, df=64, p= 0.005). By this men had longer AL than women. This was consistent with the study of Atchison *et al* (2008) who reported that males had longer axial lengths (0.62 mm) than females. Some previous studies estimated differences in AL between males and females between a range of 0.47 mm and 0.65 mm.[36-38] Also, Shufelt *et al*[13], also asserted that AL varies with gender, the difference between the males and females being significant, both overall and at each age group (p<0.0001). This difference remained significant even after adjusting for height (p<0.0001). Weihua *et al*[55] agreed that women tend to have a shorter AL, partly explained by stature, this was in line with the findings in this study. This finding could be attributed to males being taller with the influence of anatomical differences, which have been reported in other studies[56]. According to a report drawn by a previous study, eyes that are larger were found between taller people and even adjustment for height can thus explain or attribute to the different findings between male and female[44].

Conclusion

The ocular parameters evaluated are important in the assessment of corneal health status therefore the differences in the measured variables, their relationship with one and another and also relationship with gender and age will be fundamental to understanding general eye health and the development of strategies that would aid in prevention, early diagnosis, treatment and management of some ocular conditions. This study has shown that there was a statistically significant positive correlation between VCD and AL. The difference in mean VCD and AL between males and females was also statistically significant.The measurement of CCT which cannot be over emphasized should be inculcated into routine examination especially on a regular basis as this is important determinant in many ocular disorders such as glaucoma. AL measurement should be carried out more often in the primary eye care management as this could give an insight to other ocular defects. Seeing that CCT decreases significantly with age, elderly individuals in the population should be screened regularly.

Global advances in primary eye care has brought about the necessity for ocular parameters in different clinical and diagnostic fields. Another important ophthalmic parameter is the axial length (AL) which is commonly needed for intraocular lens power calculation before cataract and refractive surgery and also aids eye care providers in the diagnosis of several eye conditions.

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Table 1
Comparing Findings with other studies

STUDY	AGE (years)	CCT (µm)	VCD (mm)	AL (mm)
Yebra-Pimentel et al.[9]	15 – 35	–	16.16 ± 0.60	23.34 ± 0.65
Chen et al.[11]	40 – 80	554.0 ± 29	–	23.3 ± 1.2
Eballe et al.[14]	5 – 75	528.74 ± 35.89	–	–
Galgauskas et al.[23]	18 – 89	544.6	–	–
Iyamu et al.[35]	20 – 69	547.0 ± 29.5	–	23.50 ± 0.70
Roy et al.[44]	8 – 70	–	15.42 ± 0.36	23.35 ± 0.87
Hashemi et al.[45]	40 – 64	–	15.72	23.14
Sanchis-Gimeno et al.[58]	40 – 70	558.0 ± 0.30	16.75 ± 1.75	24.58 ± 1.73
Fahmy[59]	18 – 27	555.54 ± 31.71	–	23.75 ± 1.01
Mercieca et al.[60]	17 – 68	535.0 ± 38	–	–
Ntim-Amponsah et al.[61]	21 – 90	530.53 ± 35.64	–	–
This study	18 – 68	536.71 ± 23.89	16.30 ± 0.80	23.60 ± 0.80

Table 2
Descriptive statistics of the measured variable of respondents

VARIABLES	AGE (years)	CCT (µm)	VCD (mm)	AL (mm)
Mean±SD	37.17±11.60	536.71±23.89	16.30±0.80	23.60±0.80
Range	18.0-68.0	490.0-649.0	14.79-18.85	22.04-26.19
SEM	1.42	2.94	0.099	0.99
Std Skew	0.66	1.42	0.75	0.77
Std Kurt	0.22	6.41	1.11	1.43
K S	1.02	0.92	0.71	1.04
P-Value	0.25	0.36	0.70	0.23
95% CI	35.75-38.59	533.77-539.65	16.27-16.50	22.6-24.6
Total	**66**	**66**	**66**	**66**

CCT = Central Corneal Thickness; VCD = Vitreous chamber depth; AL= Axial Length; SD= Standard deviation; SEM = Standard Error of Mean; Std Skew= Standard Skewness; Std Kurt= Standardized kurtosis; K – S= Kolmogorov – Smirnov Z Score; CI = Confidence Interval.

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Table 3
Descriptive statistics of measured variables by Gender

Variables	CCT (µm)	VCD (mm)	AL (mm)
Male (n=31); Mean±SD	536.71±28.38	16.63±0.89	23.89±0.78
Female (n=35); Mean±SD	536.71±19.50	16.14±0.66	23.35±0.74
Unpaired t-test	0.001	2.571	2.90
P Value	>0.05	0.015	0.005
M-W	515.0	356.0	310.0
P value	0.72	0.017	0.003
K-Z (2-sample)	0.47	1.34	1.38
P Value	0.98	0.055	0.044
Df	64	64	64

CCT= Central Corneal Thickness; VCD= Vitreous chamber depth; AL= Axial Length; SD= Standard deviation;
M-W= Mann-Whitney U; K-S= Kolmogorov-Smirnov; Df= Degree of freedom

Table 4
Pearson's Correlation Coefficient between Measured Variables

Variables	CCT (µm)	VCD (mm)	AL (mm)
Age	- 0.20 (0.12)	- 0.07 (0.58)	0.078 (0.53)
CCT		0.14 (0.91)	0.032 (0.80)
VCD			0.83 (<0.0001)

CCT= Central Corneal Thickness; VCD= Vitreous chamber depth; AL= Axial Length

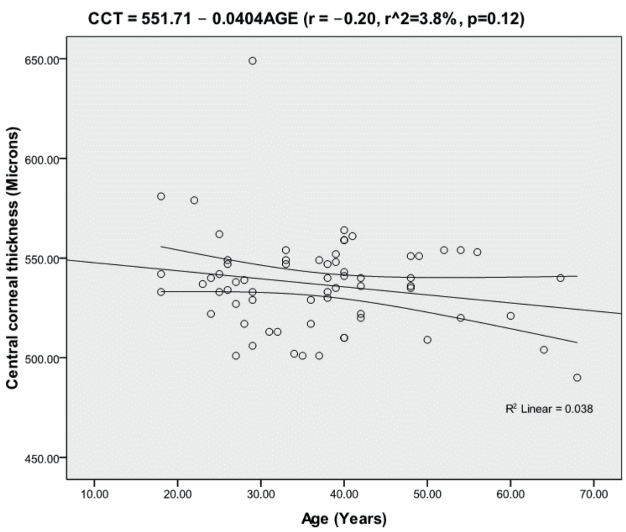

Fig. 1: Correlation of central corneal thickness and age with the linear regression line with 95% confidence interval of the regression line.

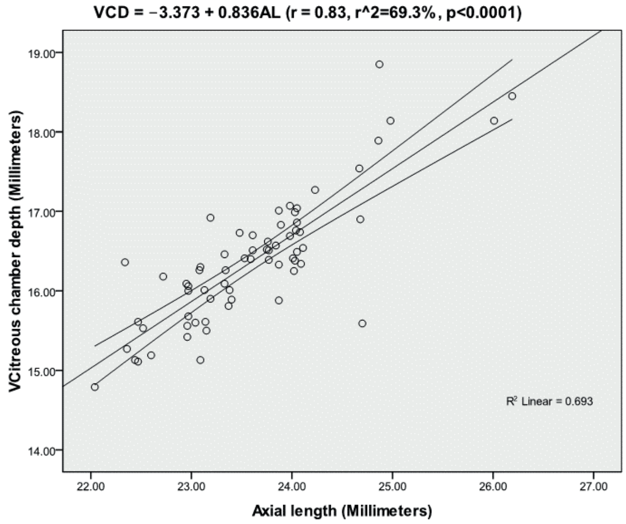

Fig. 2: Correlation of vitreous chamber depth and axial length with the linear regression line with 95% confidence interval of the regression line.

Disclamer

This is to certify that this article has not been previously published in any journal.